# Probing carrier dynamics via gap states using time-resolved STM

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Localized gap states in semiconductors exchange carriers with valence or conduction bands. Probing and understanding the carrier dynamics between confined electronic states and the states in the bands become increasingly important, as the size of semiconductor devices becomes smaller. This could be possible by shaken pulse-paired excited scanning tunneling microscopy (SPPX-STM) [1], which enables us to directly image how carriers behave in semiconductors with sub-picosecond temporal and atomic-scale spatial resolutions. Here we report on the influence of surface states on carrier dynamics investigated by SPPX-STM.

For SPPX-STM measurement, the tunnel gap of STM is illuminated by a sequence of paired pulses (Fig. 1) and the corresponding change in tunneling current $\Delta I$ is measured as a function of delay time between the pulse pair. Co was deposited onto a cleaved GaAs surface in an ultrahigh vacuum chamber. We measured time-resolved tunneling current ΔI vs. delay time, and obtained the image of carrier decay time (Fig. 2). The carrier decay time is much shorter for Co than for GaAs. This difference is explained by the existence of the surface state at the Co site, which is absent for GaAs; The carrier trap and recombination at the Co-derived surface state are responsible for the fast decay at Co (Fig. 3). From the dependence of decay time on the tunneling rate, we can deduce the carrier capture rate. Details will be discussed at the presentation.

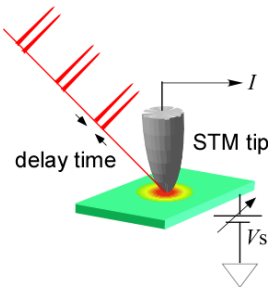


Fig. 1 Schematic of SPPX-STM measurement.

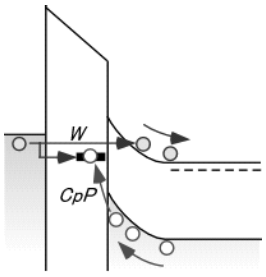


Fig. 3 Carrier dynamics via Co-derived gap state.

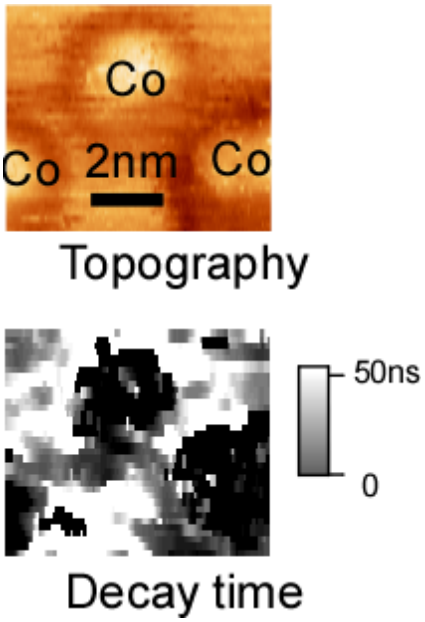


Fig. 2 STM topography and image of carrier decay time on Co/GaAs.

## References

1) Y. Terada, M. Aoyama, H. Kondo, A. Taninaka, O. Takuechi and H. Shigekawa, Nanotechnology **18**, 44028 (2007).